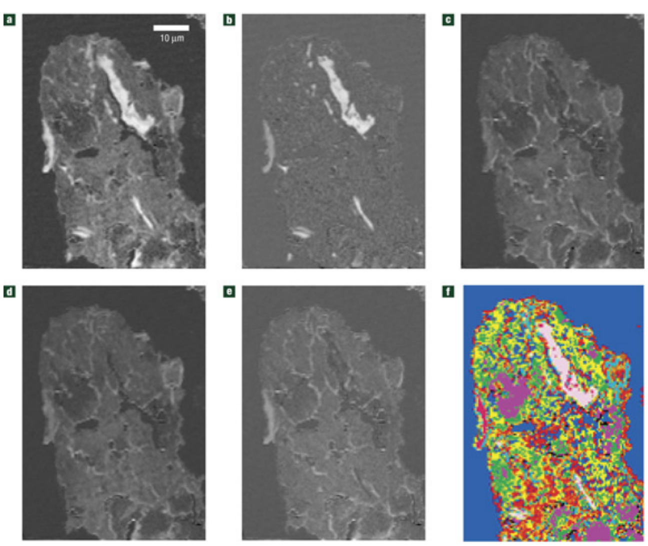
First Nanoscale Image of Soil Reveals an 'Incredible' Variety

A handful of soil is a lot like a banana, strawberry, and apple smoothie: Blended all together, it is hard to tell what's in there, especially if you have never tasted the fruits before.

But when you look at soil's organic carbon closely, it has an incredible variety of known compounds. And looking closely is exactly what Cornell researchers have done for the first time – at a scale of 50 nanometers (1 nanometer equals the width of three silicon atoms). Until now, handfuls of soil humus (or the organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms) looked remarkably similar.

According to a study published in the April issue of *Nature Geoscience*, knowing the structure and detailed composition of soil carbon could provide a better understanding of the chemical processes that cycle organic matter in soil. For example, the research may help scientists understand what happens when materials in the soil get wet, warm or cool and how soils sequester carbon, which has implications for climate change.

"There is this incredible nanoscale heterogeneity of organic matter in terms of soil," said Johannes Lehmann, a Cornell associate professor and lead author of the study. "None of these compounds that you can see on a nanoscale level looks anything close to the sum of the entire organic matter."



Distribution of carbon contents and molecular forms in a soil microassemblage from Nandi Forest (Kenya) determined by NEXAFS in combination with STXM. a) Total carbon. b) Aromatic carbon. c) Aliphatic carbon. d) Carboxyl carbon. e) Phenolic carbon. f) Cluster map of carbon forms.

The soil measurements (actually, images produced by a highly focused x-ray beam) were made at NSLS beamline X1A1 using an x-ray spectromicroscopy method developed by physicists at Stony Brook University. The method allowed the researchers to identify forms of organic carbon in the samples.

While the composition of organic carbon in soils from North America, Panama, Brazil, Kenya or New Zealand proved remarkably similar within each sample, the researchers found that within spaces separated by mere micrometers, soils from any of these locations showed striking variation in their compositions. For example, the compounds that "hang on the right and left of a clay mineral may be completely different," said Lehmann.

The researchers were also able to identify the origins of some of the nano-sized compounds, determining that some of them, for example, were microbe excretions and decomposed leaves.

The researchers also recognized patterns of where types of compounds are likely to be found at the nanoscale.

"Now we can start locating certain compounds," Lehmann said. "We find black carbon as distinct particles in pores, whereas we find microbial products smeared around surfaces of minerals."

The method now allows researchers to break soil down, separate compounds, conduct experiments on individual compounds and better understand the interactions, Lehmann said.

The research was funded by the National Science Foundation.

For more information, please see: J. Lehmann, D. Solomon, J. Kinyangi, L. Dathe, S. Wirick, and C. Jacobsen, "Spatial Complexity of Soil Organic Matter Forms at Nanometre Scales," Nature Geosci., 1, 238-242 (2008).

— Krishna Ramanujan, Cornell University